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Agricultural Memorandum No 850

PARASITIC GASTRO-ENTERITIS IN LAMBS - A MODEL FOR ESTIMATING THE TIMING OF THE LARVAL EMERGENCE PEAK.

Introduction.

The life history of the nematode parasites of domestic ruminants usually involves the development and survival of free-living stages on pasture. The pasture is, therefore, the site of deposition, development and transmission of nematode infection and meteorological factors affecting the pasture will affect the parasites.

In a recent paper Thomas and Starr (1978) discussed a technique for forecasting the timing of the summer wave of gastro-intestinal parasitism in North-East England in the lamb crop using meteorological data and in particular estimates of the duration of 'surface wetness'.(See also Ag.Mem 765).

Such predictions have potential value in parasite control. Successful correlations between weather and the bionomics of helminth eggs and larvae have been documented by Michel (1976) and have become the basis for forecasting,for example, fascioliasis (Ollerenshaw & Rowlands, 1959) and nematodiriasis (Smith and Thomas 1972) in the U.K.

That work suggests that the relationship between the 'synoptic scale' meteorological environment and the micro-meteorological environment of the helminth eggs and larvae are such that the former can be correlated with epidemiological findings.

This paper presents an attempt at 'modelling' some of the complex and interacting factors influencing the development of egg and larval stages. It incorporates and extends Thomas' and Starr's ideas of developmental dependence on 'surface wetness' and of temperature limitation to development.

Data sources

a. Pasture larval counts at Cockle Park, (NE England),1967 to 76 made by Dr R J Thomas - (figs 1a to j). The pasture was sampled at weekly, sometimes fortnightly intervals.

b. The Meteorological Office 'effective rainfall' program for short-rooted vegetation at Cockle Park. Daily estimates of potential evapotranspiration (pe) are made and tabulated against the daily rainfall(R).

c. Estimates of daily 'degree-days above 10°C' based on daily maximum and minimum temperatures at Cockle Park.

Methodology.

Levine (1963, 78) used bioclimatographs and graphs of average monthly rainfall and pe to illustrate the general epidemiologic situations at various locations. The methodology of this paper is to estimate the 'state' of the pasture using daily rainfall and pe information.

a. The assumption is made that the surface layer of pasture remains 'moist' from recent rainfall (and hence potentially suitable for egg/larval development) until more than 10mm of 'pe' have occurred from the layer.

b. This layer can be 'topped-up' to a maximum water content of 10 mm by rainfall; rainfall in excess of this passes to lower soil layers where it is inaccessible to the surface layer.

c. Development from the nematode egg through to the third ('active') larval stage is taken as occurring whenever the environmental (screen) temperature rises above 10°C; the daily incremental development rate is taken as proportional to the daily accumulation of degree days when the surface layer is moist.

The date at which the degree-day summation attains 130 units seems to fit the observed larval peak incidence quite well. (fig. 1 a-j).

Calculation.

i. Commence when soil is still at field capacity.

ii. 'Effective rainfall' (R-pe, when this is positive) is found day by day and accummulated to a maximum of 10mm.

iii. When 'effective pe'occurs (R-pe when this is negative) this is subtracted from the water content of the surface layer until surface layer becomes dry.

iv. Subsequent effective rainfall tops up the surface layer; the 'moist' or 'dry' state of the layer are noted over the spring and summer months(commencing 16 April when stock was put out).

v. Degree days above 10°C are summed for 'moist' days.

vi. On days when rain fell but pe >R the duration of moistness is taken as $\frac{R}{pe}$ and this proportion of degree days is assigned. Similarly at the end of a moist spell there will generally be a few mm left to be evapotranspired, again leading to a proportional assignation of degree-days on the last day.

The procedure is illustrated by an example from Cockle Park - 16 June to 2 August 1970 (Table 1). The inhibiting influence of low temperatures on development is illustrated by data for May 1968(Table 2); there are many 'moist' days but on only a few did maximum temperature rise above 10°C (ie degree days above 10°C are generally zero).

Discussion of the technique.

Rainfall is read at 0900 GMT and 'thrown back' to the previous day. The methodology implies that rain fell at a time such that the soil was subject to the full degree day total for that day. In fact for overnight rainfall the degree day total appropriate is that for the following day.

This uncertainty over rainfall timing and hence of daily duration of surface wetness will introduce only small errors in degree-day summation when the soil is moist for days at a time: if a cycle of wetting and drying occurs with moist states pertaining for only say 3 or less days each time, larger errors may be introduced.

Table 1 illustrates these two cases, ie: bigger errors in degree days due to duration uncertainties during 22-24 June and 3, 9-11 and 14 July than over the extended period 27 June-3 July; 18 July-1 August.

Screen maxima and minima are used to deduce degree-days, appropriate to the soil surface, and we further assume the development is proportional to the degree-day total with a cut off at 10°C. There is evidence that rate of development is a non-linear function of temperature.

The development of the egg to the appropriate larval stage may occur mainly on the pasture if the faecal pat is initially diarrhoeic or is broken down by trampling and/or rainfall; development might occur entirely within the pat if these conditions are not found.

However the model assumes that only a limited amount of incident rainfall remains available to maintain moistness and would therefore seem to have application to the pat situation as well. Thus the moisture is evaporated from the pat at potential rate as in the surface layer case. We can argue whether 10 mm would then be a reasonable limit for water content; however the methodology would be the same.

Finally the methodology assumes that dessication does not inhibit or retard the re-commencement of egg/larval development once conditions become favourable again; dessication is known to reduce the population.

Discussion of the results.

Estimated emergence dates based on a degree day above 10°C count of 130 are presented in fig 1 a-j . In seven of the ten years the count lay within the range of dates possible as shown by the observed larval counts. The count was a week in advance of the observed maximum peak in 1967 but that season Cockle Park temperature data were not available and were estimated from a site some 20 km away. The hot, dry summer of 1976 produced a low larval population with a maximum comparable to the 'background' count in other years. The estimated emergence is in the middle of September, (in agreement with date calculated by the method of Thomas & Starr 1978). The 1972 larval count was again low; the estimated emergence was in mid August.

Summary

The methodology accounts for the 'concertina effect' observed - eggs are generally deposited on pasture over a longer period than that over which the emergence peak occurs. (The effect, apparently due to temperature limitation to development, is corrected for empirically by Thomas and Starr).

With perhaps slight modification to the 'layer capacity' the model applies to development within the faecal pat as well as on pasture.

More accurate daily estimates of pe are in sight; it remains to model more accurately the dependence of development rate on degree-days. A limit to accuracy here is set by the comparatively infrequent sampling of the larval burden. It is difficult to see how the 'duration of wetness' could be either better estimated using only daily rainfall data.

References

Levine N D (1963) Advances in Vet Sci 8 p 212-61

" " (1978) WMO Tech Note; 159, p 51-57

Michel J F (1976) Advances in Parasitology; 14, p 355

Ollerenshaw C B and Rowlands W T (1959) Vet Record; 71, p 591

Smith L P and Thomas R J (1972) Vet Record; 90 p 388

Thomas R J and Starr J R (1978) Vet Record 103, p 465-468

By J.R. Starr.

Legend

Fig 1 (a-j) Pasture larval counts at Cockle Park 1967-76. Units: infective larvae per kgm of grass. (Note: a change of sampling system after 1973).

Weekly sampling data, tabulated by Thomas and Starr are here presented graphically. The lines, keyed on each graph, show the period within which sampling occurred; The dotted .... line indicates that a week or more elapsed between samplings. Vertical arrows on each graph show estimated peak emergence date based on the model.

Tables

1. Illustration of methodology using Cockle Park daily rainfall (R) and potential evapotranspiration (pe) for 1970.

2. Illustration of the inhibiting influence of low temperatures on egg/larval development: Cockle Park, May 1968.

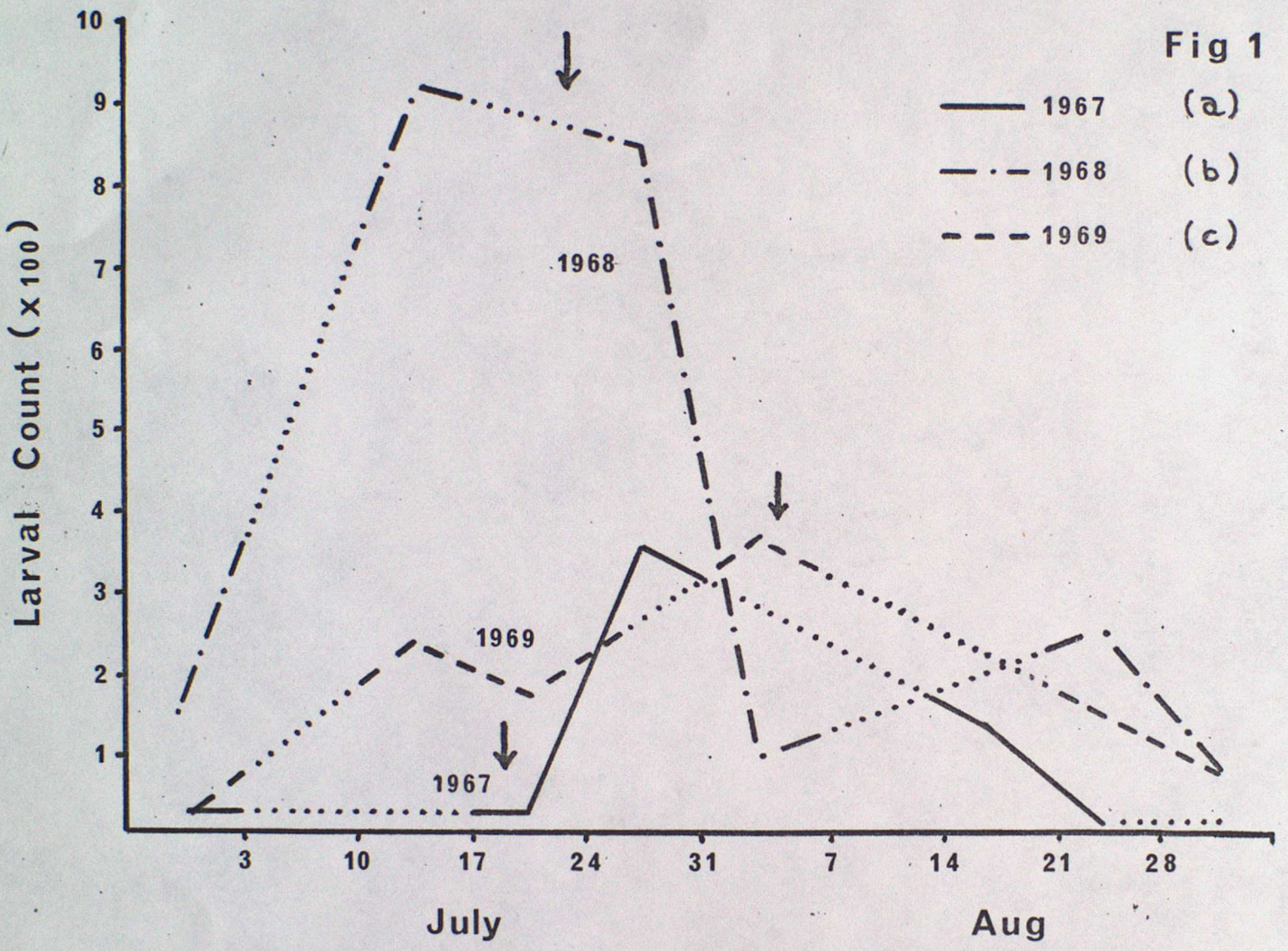
Fig 1
1967 (a)
1968 (b)
1969 (c)
Larval Count (x100)
10
9
8
7
6
5
4
3
2
1
1968
1969
1967
3
10
17
24
31
7
14
21
28
July
Aug

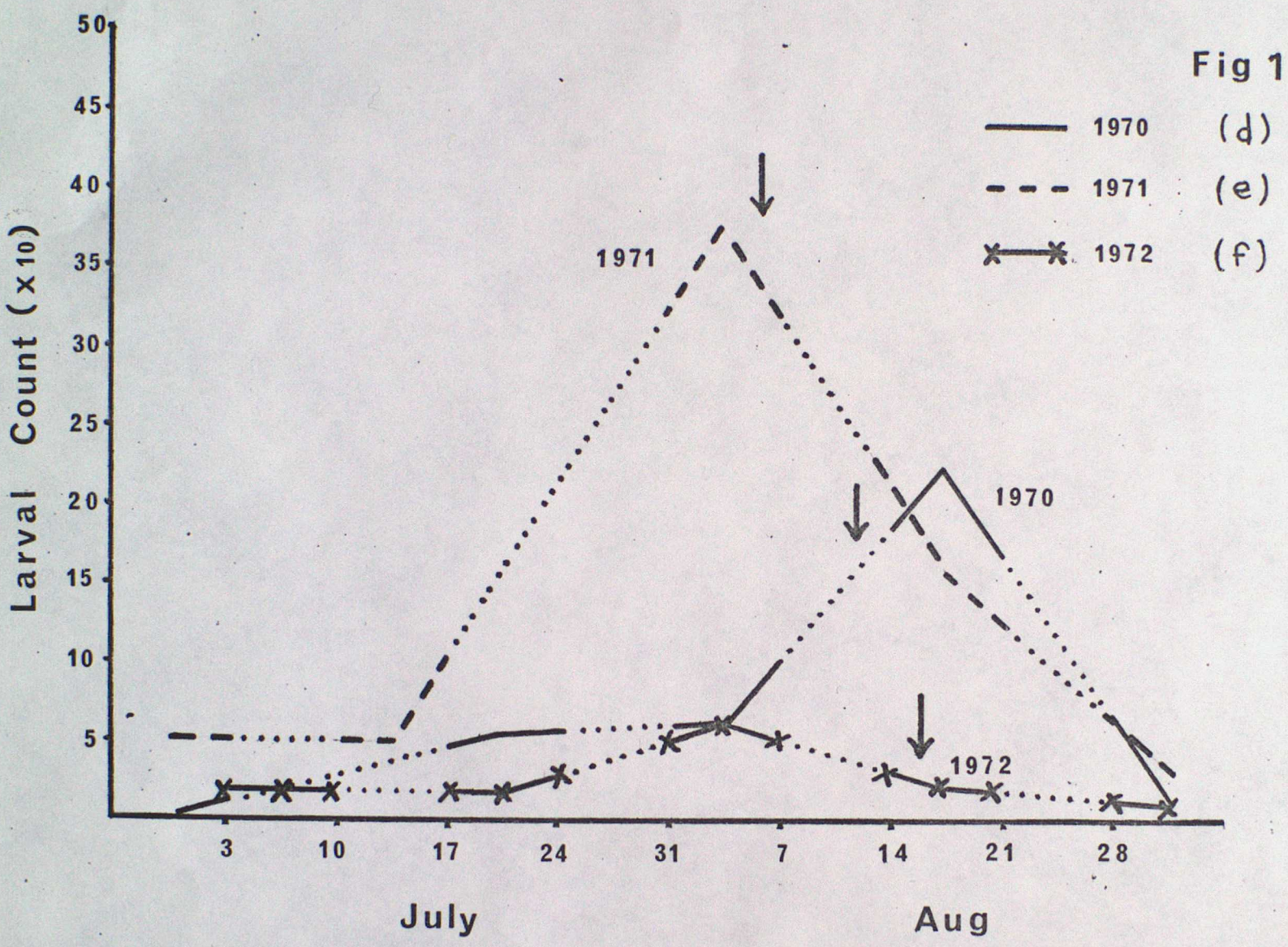
Fig 1
1970 (d)
1971 (e)
1972 (f)
Larval Count (x10)
50
45
40
35
30
25
20
15
10
5
1971
1970
1972
3
10
17
24
31
7
14
21
28
July
Aug

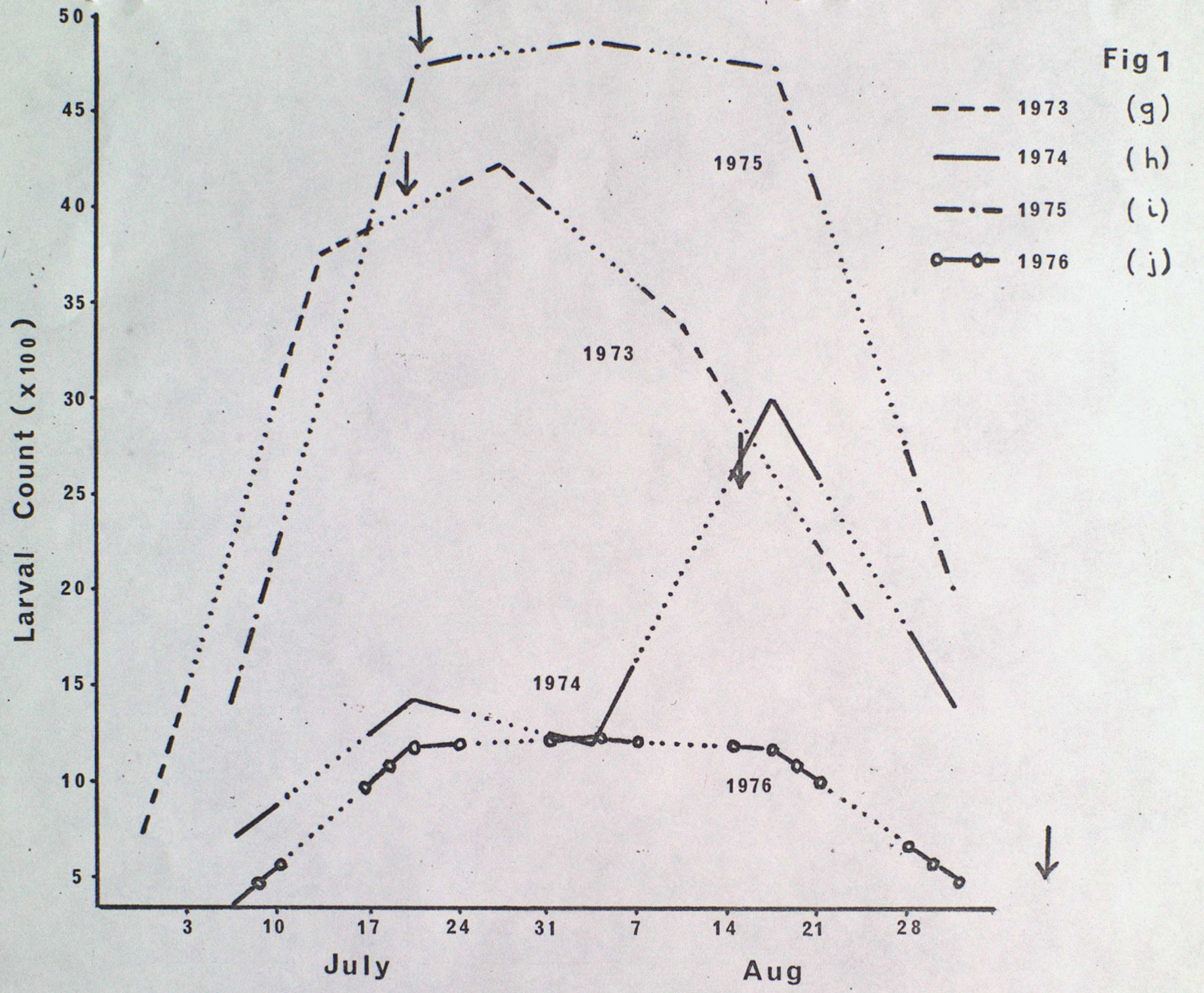
Fig 1
1973 (g)
1974 (h)
1975 (i)
1976 (j)
Larval Count (x100)
50
45
40
35
30
25
20
15
10
5
1975
1973
1974
1976
3
10
17
24
31
7
14
21
28
July
Aug

Table 1

	Date	R	pe	(R-pe)	Moisture status of top layer	Degree Days: (DD)	Proportion of DD's ascribed to day	Daily DDs
June	16	0.0	3.0	-3.0	DRY	1.7	0	0
	17	0.0	3.0	-3.0	"	1.2	0	0
	18	0.0	3.0	-3.0	"	3.6	0	0
	19	0.0	"	-3.0	"	3.6	0	0
	20	0.0	"	-3.0	"	6.6	0	0
	21	0.0	"	-3.0	"	5.3	0	0
	22	1.5	"	-1.5	moist	7.2	1.5/3.0	3.6
	23	2.8	"	-0.2	"	3.4	2.8/3.0	3.2
	24	1.0	"	-2.0	"	5.5	1.0/3.0	1.8
	25	0.0	"	-3.0	Dry	3.9	0	0
	26	0.0	"	-3.0	"	3.9	0	0
	27	7.9	"	4.9	4.9	4.7	1	4.7
	28	3.0	"	0	4.9	5.0	1	5.0
	29	1.5	"	-1.5	3.4	4.2	1	4.2
	30	0.3	"	-2.7	0.7	4.6	1	4.6
July	1	5.3	2.8	2.5	3.2	2.6	1	2.6
	2	0.0	"	-2.8	0.4	2.6	1	2.6
	3	0.0	"	-2.8	moist	3.5	0.4/2.8	0.5
	4	0.0	"	-2.8	Dry	2.6	0	0
	5	0.0	"	-2.8	"	4.6	0	0
	6	0.5	"	-2.3	moist	7.2	0.5/2.8	1.3
	7	0.0	"	-2.3	Dry	7.8	0	0
	8	2.8	"	0	moist	10.5	1	10.5
	9	1.3	"	-1.5	moist	4.4	1.3/2.8	2.0
	10	4.1	"	1.2	1.2	2.9	1	2.9
	11	0.0	"	-2.8	"	2.2	1.2/2.8	0.9
	12	0.0	"	-2.8	Dry	4.7	0	0
	13	0.0	2.7	-2.7	"	5.0	0	0
	14	2.3	"	-0.4	moist	3.1	2.3/2.7	2.6
	15	0.0	"	-2.7	Dry	2.8	0	0
	16	0.0	"	-2.7	"	4.2	0	0
	17	0.0	"	-2.7	"	6.9	0	0
	18	11.4	"	8.7	8.7	4.7	1	4.7
	19	2.5	"	-0.2	8.5	1.9	1	1.9
	20	9.1	"	6.4	10	1.9	1	1.9
	21	2.8	2.6	0.2	10	1.9	1	1.9
	22	4.1	"	1.5	10	1.8	1	1.8
	23	8.6	"	6.0	10	3.6	1	3.6
	24	31.2	"	28.6	10	3.9	1	3.9
	25	3.0	"	0.4	10	3.9	1	3.9
	26	0.3	"	-2.3	7.7	1.7	1	1.7
	27	9.1	2.5	6.6	10	3.3	1	3.3
	28	0.0	"	-2.5	7.5	6.7	1	6.7
	29	0.0	"	-2.5	5.0	4.7	1	4.7
	30	1.0	"	-1.5	3.5	5.8	1	5.8
	31	0.0	"	-2.5	1.0	7.2	1	7.2
Aug	1	0.0	2.4	-2.4	moist	8.3	1.0/2.4	3.5
	2	0.0	2.4	-2.4	Dry	9.4	0	0
					etc			

Table 2

Date		R	pe	(R-pe)	Moisture status of top layer	Degree Days: (DD)	Proportion of DD's ascribed to day	Daily DDs
May	1	3.8	1.5	2.3	2.3	0.1	1	0.1
	2	2.5	1.6	0.9	3.2	0.0	1	0.0
	3	6.3	"	4.7	7.9	0.0	1	0.0
	4	6.9	"	5.3	10	0.0	1	0.0
	5	0.0	"	-1.6	8.4	0.5	1	0.5
	6	0.8	"	-0.8	7.6	0.0	1	0.0
	7	0.0	1.7	-1.7	5.9	0.0	1	0.0
	8	0.0	"	-1.7	4.2	0.0	1	0.0
	9	5.3	"	3.6	7.8	0.0	1	0.0
	10	0.0	"	-1.7	6.1	0.7	1	0.7
	11	16.5	"	14.8	10	0.5	1	0.5
	12	2.3	"	1.2	10	0.5	1	0.5
	13	0.0	1.8	-1.8	8.2	0.5	1	0.5
	14	6.1	"	4.3	10.0	0.5	1	0.5
	15	0.8	"	-1.0	9.0	1.4	1	1.4
	16	0.5	"	-1.3	7.7	0.0	1	0.0
	17	0.0	"	-1.8	5.9	0.0	1	0.0
	18	0.0	1.9	-1.9	4.0	0.0	1	0.0
	19	0.3	"	-1.6	2.4	0.0	1	0.0
	20	1.0	"	-0.9	1.5	0.0	1	0.0
	21	0.0	"	-1.9	moist	0.0	1.5/1.9	0.0
	22	0.0	"	-1.9	Dry	0.0	0	0.0
	23	0.0	1.9	-1.9	"	0.3	0	0.0